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(54) CATALYTIC REACTOR MATRIX FOR CLEANING INTERNAL COMBUSTION ENGINE EXHAUST GASES AND A METHOD OF MANUFACTURING THE SAME

(71) I, MANFRED BEHR, a German citizen trading as SUDDEUTSCHE KUHLERFABRIK JULIUS FR. BEHR, of Mauserstrasse 5. 7 Stuttgart 30, Germany, do hereby declare

the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a matrix for a catalytic reactor for purifying the exhaust gases of internal combustion engines, more particularly the so-called "Otto" engines of motor vehicles.

Owing to modern legislation on exhaust gas pollution in many countries, it is necessary to free the exhaust gases of vehicle engines to a considerable extent from injurious substances. For this purpose it is necessary to transform carbon monoxide (CO), unburnt hydrocarbons (HC) and oxides of nitrogen (NO_x) into non-toxic combustion products by after-burning.

Measures for keeping the emission of injurious substances to a minimum by means of a corresponding procedure for operating the internal combustion engine are not adequate and to enable the required limit values to be observed, thermically or catalytically acting reactors are used.

In the case of catalytic reactors used for reducing the injurious substances in exhaust gases, reduction catalysts and oxidation catalysts are sometimes used conjointly in the form of so-called double bed catalysts.

Platinum, palladium, copper oxide and nickel oxide and similar substances are used as catalysts. The catalyst requires a catalyst support which offer the required dimensions or surface area to the catalyst and holds the entire system together and gives it strength. Known catalyst supports consist of aluminium oxides. They are used as honeycomb elements and as loose or bulk material. In the case of the bulk materials for example in the form of granules, it is also known to use metallic supports in the form of a ring or saddle, generally made of materials having a high nickel content such as Monel (Registered Trade Mark), which displays a catalytic activity after conversion into nickel oxide and copper oxide.

Honeycombed elements made of aluminium oxide are known as so-called supporting matrices for exhaust gas catalysts. However, aluminium oxide is an extremely brittle material, consequently strength disadvantages arise in the long term. Under the vibrations which occur in service due to shock waves in the exhaust gas stream or due to the travelling movements and engine vibrations, the material crumbles relatively rapidly. It is therefore necessary to protect the catalyst support against mechanical vibrations of the vehicle and/or of the engine by resilient suspension means. Aluminium oxide also possesses a lower coefficient of thermic expansion compared to steel. Because the supporting matrix has to be embedded in a metallic housing for assembly purposes, continual relative movements occur between the housing and the matrix at the fluctuating temperatures from —20 to +900°C which occur during service, and these movements must also be absorbed by resilient members. Temperature stresses and play resulting from the fatigue of the resilient material result in the destruction of the support material. As a result of the resilient assembly of the honeycomb element in the reactor housing, sealing problems occur which have to be remedied by special seals and are intended to cause the total exhaust gas to be forced through the honeycomb element and not to flow past the latter between the honeycomb element and the housing.

Aluminium oxide is furthermore a porous substance, the porosity of which is a function of the sintering temperature. Consequently the sintering temperature also has a considerable influence upon the subsequent catalytic efficacity. At excess temperatures

the already coated support sinters out further, closes its pores and thereby reduces the surface available for the catalytic activity. Furthermore the porosity is a function of impurities in the petrol. Aluminium oxide is moreover a poor conductor of heat. In the case of local accumulations, more particularly of unburnt HC, therefore, local overheating occurs, which leads to local burning away of the support. In addition, the strength of aluminium oxide is low, so that honeycomb wall thicknesses of not less than 0.2 mm must be chosen.

Bulk materials are constructed mainly from aluminium oxide, and for this reason they have the same disadvantages as the aluminium oxide honeycomb elements, which are due to the properties of the material. Furthermore, these bulk materials exhibit a very high pressure loss. The bulk material density varies under the gas and mechanical vibrations which prevail during service, so that cohesion between individual granules of the bulk material ceases to exist, individual granules strike one another and at the same time abrade each other. A further disadvantage, as in the case of aluminium oxide honeycomb elements, is the different coefficient of expansion of the bulk material compared to the steel envelope.

Bulk materials which consist of nickel alloys such as Monel (Registered Trade Mark) have the disadvantage that the alloy possesses too low a thermal strength. Bulk fills of this material melt when higher temperatures occur, with the result that the entire reactor is destroyed.

However, in the case of bulk materials the coating with a catalyst material can be performed in a continuous process, in which case the reactor housing is filled with the coated bulk material only after the said coating process is complete.

It is the underlying aim of this invention to produce a supporting matrix which does not suffer from the disadvantages of the known supports and furthermore combines the advantages of a honeycomb structure with those of bulk materials.

According to the invention there is provided a catalytic reactor matrix for cleaning the exhaust gases of an internal combustion engine, wherein said matrix comprises alternate flat and corrugated sheets of heat-resistant steel, as hereinafter defined, said sheets being coated with a catalytically active material.

The heat-resistant steel referred to above is a steel alloy, which possesses resistance to corrosion in an atmosphere of internal combustion engine exhaust gases. Such alloys are well-known and are based on the inclusion of chromium and nickel. The properties of these steels can be further improved by the addition of silicon, aluminium, niobium or tungsten.

The invention also provides a method of manufacturing a matrix of the above kind, comprising continuously feeding two strips of heat-resistant steel through a continuous coating bath in which said strips are coated with a catalytically active material, one of said strips having been passed previously through a corrugating means, arranging the coated strips in alternate laminations and securing the laminations together.

In the case of bulk catalysts it is known to arrange the catalyst particles in a dense packing in each catalyst bed. Wires, fibres, corrugated bands, foils, spirals, envelopes, tubes or the like have already been proposed as supports for the catalyst material in this form. In a known method of exhaust gas purification, particles are used which have been produced by cutting treatment of metal. In this case however a high pressure loss occurs and there is a relatively high risk of contamination. The system settles slowly, because the extremely dense packing which is desired cannot be achieved from the outset.

A catalytic convertor is also known in which the catalyst bed consists of at least one part defining a first channel and at least one part defining a second channel, the first and second parts are flat and corrugated plates which carry a catalyst upon their surface, and the first and second parts are placed one above the other in such a manner that the axes of the first and second channels cross each other. In this case the gas stream is plurally diverted, so that high pressure losses occur. Furthermore, the manufacture of this convertor is difficult and complicated.

In another known method of reducing mitrogen oxides a catalytic part is used which exhibits a mesh-shaped structure and can be fabricated of steel. In this case it is necessary for the gas stream to flow transversely through the catalytic part, which leads to high pressure losses, and assembly difficulties result owing to the requirement to keep the passages or channels open. The gas channels are not arranged regularly, but in a random and chaotic manner.

In the case of known catalysts which consist of metal alloys, the different alloys themselves have a reducing action for the NO_x. In contra-distinction thereto, the present invention employs a heat-resistant steel as the supporting matrix for the catalyst material, and it is particularly advantageous that the steel used is itself catalytically inactive.

In order to obtain a large effective surface, it is particularly convenient if the width and the height of the cross-section of the individual cells formed between the sheets are smaller than 1.5mm.

It is particularly advantageous if the wall thickness of the supporting sheets is less than 0.1mm since this leads to a relatively firm structure.

Honeycomb elements according to the invention do not modify their surface structure at high temperatures. Due to the separation of the functions of a support, namely strength and cohesion on the one hand, from the function of catalytic activity on the other hand, considerable advantages result. The small wall thicknesses lead to considerably smaller pressure losses. The individual honeycomb cells can be made smaller, so that large geometrical surfaces can be incorporated in relation to the overall volume.

It is particularly advantageous for the manufacture if the profile of the corrugation of the corrugated part of the supporting matrix corresponds to the profile of an involute gear tooth. By this means an extremely compact structure of the honeycomb cells is achieved and the occurrence of local accumulations of catalyst which lead to an increased requirement of catalyst material without enlarging the effective surface is avoided.

The supporting matrix can be constructed in an advantageous manner in that the sheets are bands which have been wound spirally together to form a cylinder. It is also possible to make the sheets of generally flat construction in a known manner and to stack plain and corrugated sheets alternately one above the other. In either case the ducts formed by the corrugations are always parallel.

It is particularly convenient to coat the steel plates, before they are stacked or coiled, with a catalytically active metal such as copper, nickel or the like, and then to oxidise them. It is also equally possible to coat the steel plates directly with a catalytically active metal oxide for example copper oxide, nickel oxide or the like.

The individual layers of the steel plates may be spot welded or brazed together. It is also possible to weld or braze them together along their whole area of contact. The resilience and strength of the matrix thus provides high reliability in service, more particularly with regard to gas and mechanical vibrations.

The catalyst supports can be manufactured in any desired lengths and shapes.

According to a preferred embodiment of the invention, the smooth and the corrugated steel plates are arranged under pre-stress in a steel envelope. Where the individual steel sheets are welded or brazed together, the envelope may be omitted. Because the envelope and the supporting matrix can consist of the same material, no difficulties occur in assembly due to different coefficients of thermal expansion and consequently no complicated res lient joints are required.

According to a preferred embodiment of invention, the plates or sheets of the matrix are attached to the envelope. The attachmen may be effected by screws, but the sheets of the matrix may also be welded or brazed to the envelope.

In the case of a cartridge consisting of a supporting matrix and an envelope, the matrix can be fixed in the envelope by retaining means preferably arranged in front of the end face of the matrix. The retaining means conveniently consist of crossed struts made of wires or bars. The struts are advantageously elastically resilient.

According to a further embodiment of the invention, the retaining means may also be constituted by wire grilles. In order to obtain the required load, it is advantageous according to a further feature of the invention if the envelope is of conical construction.

According to another feature of the invention, the externally placed end of the band is cut obliquely to the longitudinal axis of the band. This likewise causes a pressing action during the assembly, which produces the stressing. It is particularly advantageous for this purpose to choose the length of the obliquely cut end so that it extends helically once around the circumference of the inside of the envelope.

The invention also embraces a catalytic reactor having a matrix according to the invention and a housing with connections for an exhaust gas inlet pipe, an exhaust gas outlet pipe, the matrix with its envelope being secured in the housing and sealed by flange rings thereto. A secondary air supply to the housing may also be provided. No sealing problems occur between the cartridge and the reactor housing, because the matrix can be screwed or welded directly into the housing by means of the flange rings. In the case of an integrally brazed or welded supporting matrix, the matrix can also be secured in the housing directly, without an envelope.

The flange rings may have a U-shaped cross-section in which case one arm of the U is attached to the housing and the other arm is attached to the envelope of the matrix. The attachment may be effected by screwing, brazing or welding.

In another embodiment of the invention, the flange rings are of Z-shaped section and the exhaust gas inlet pipe and/or the exhaust gas outlet pipe is or are fastened between the internal flange of the corresponding Z-shaped flange ring and the envelope of the matrix.

In one embodiment of the invention, a first catalytic reactor matrix serving as a reduction catalyst and a second catalytic

reactor matrix serving as an oxidation catalyst are arranged in the said housing. In this case it is advantageous if spacing struts are arranged between the reduction catalyst and the oxidation catalyst, and a secondary air connection communicates with the matrices in the region of the spacing struts.

The space between the outermost ring flanges and the inner wall of the housing on the one hand and the envelope of the supporting matrix or the supporting matrix itself on the other hand is packed with insulating material, for example, glass wool, asbestos or the like.

A further advantage of the supporting matrix according to the invention, or of a catalytic reactor according to the invention, is found to be the high thermal conductivity of the steel used as a supporting material for the matrix, whereby local overheating can be better dissipated to colder parts of the matrix and local burning away is largely eliminated. Furthermore the small wall thickness which can be used leads to a low thermal capacity, so that the heating up time until the catalyst comes into effect is shorter than in the case of catalysts hitherto known.

It is particularly advantageous if, when manufacturing the matrix, the coasting of the bands with the catalytic material is effected continuously and before the stacking or rolling up to form the supporting matrix. The supporting matrix is then pressed into an envelope, for example by the use of a multiple jaw chuck.

Some embodiments of the invention and the method of their manufacture will now be described by way of example and with reference to the accompanying drawings, in which:—

Figure 1 shows a spirally wound supporting matrix according to the invention;

Figure 2 shows a cartridge with a supporting matrix in an envelope;

Figure 3 shows a partial section of a laminated supporting matrix;

Figure 4 shows schematically a catalytic reactor with a supporting matrix according to the invention, in oblique elevation and partly sectioned;

Figure 5 shows a longitudinal cross-section through a modified form of reactor;

Figure 6 shows a detailed section of part of a further modified form of reactor; and

Figure 7 shows schematically an apparatus for performing the method according to this invention.

Figure 1 illustrates a supporting matrix 13 according to the invention in the coiled state. The supporting matrix 13 is manufactured of high temperature steel, and comprises a smooth intermediate band 1 and a corrugated band 2, which are coated with catalyst material. In the embodiment of Figure 1, the smooth intermediate band 1 and the corrugated band 2 are wound spirally upon a core 3. The coiled supporting matrix 13, after it has attained the desired diameter, is surrounded with an envelope 4, so that a cartridge 20 is formed.

Figure 2 shows a retaining means 21 in the form of crossed bars, which serve to secure the supporting matrix 13 in the envelope 4 of the cartridge 20. Here the bars 21 are bent in order to be able to adapt themselves resiliently to any thermal expansions of the envelope 4. The arrangement and number of the bars 21 is a matter of choice, it is possible for only one bar, preferably oriented diametrically, to be provided, but preferably two bars are arranged in a crossed pattern; the bars may be made of sheet metal strips or of wires and may be straight or curved as illustrated.

The diameter of the supporting matrix 13 and its length, and likewise the length of the cartridge 20, can be governed by the particular requirements of each case.

For the embodiment of Figure 3, a sandwichlike structure is schematically illustrated, in which smooth intermediate sheets or plates 1 and corrugated sheets 2 alternate one above the other. The external contours of the stack may be freely chosen, but are preferably rectangular or cuboidal.

Figure 4 illustrates schematically and partly sectioned, a catalytic reactor with two supporting matrices or cartridges according to the invention. The reactor 23 comprises a housing 16 with an exhaust gas inlet pipe 14 and an exhaust gas outlet pipe 15. A secondary air connection 17 is provided between the two supporting matrices. The cartridges 25, 26 may be fixed in the housing 16 by flanges 19. Flanges 19 may be brazed or welded to the housing 16 or screwed thereto by means of screws 18. The flange 19 may be of L-shaped, U-shaped or Z-shaped construction, while the fixing screws 18 are fitted to an angled flange part, or in the case of a U-profile or Z-profile, to both flange parts. A sealing is achieved between the cartridges 25 and 26 and the interior of the housing in the housing 16 by the flanges 19.

As may be seen from Figure 4, no sealing problems arise between cartridges and housing 16, because the cartridges 25 and 26 are fixed directly in the housing 16 through the flanges 19.

The embodiment illustrated in Figure 4 relates to a so-called double-bed catalyst, in which the upstream catalyst 25 in the flow direction is constructed as a reduction catalyst and the second or downstream catalyst located behind the first (to the right in the Figure) as an oxidation catalyst. The secondary air inlet connection 17 is provided between the reduction catalyst 25 and the oxidation catalyst 26.

As has been mentioned, the supporting matrix 13 is adavantageously introduced into its envelope 4 with a pre-stress. This can be achieved, for example, in that, as indicated in the case of the right hand catalyst 26 in Figure 4, the envelope 4 of the cartridge 26 is of frusto-conical construction. When the wound supporting matrix is pressed in, the requisite pressure to generate the stressing is then achieved.

A further possibility of achieving the desired pre-stress is illustrated in Figure 2, where the outer ends of the coiled sheets forming the supporting matrix 13 is cut not at right angles to the longitudinal direction of the band, but obliquely, whereby an oblique edge 24 is produced. The angle of the external circumference of the matrix axis in this case is chosen such that the length of the cut edge is longer than the internal circumference of the envelope 4, so that the cut edge runs helically once around the external circumference of the matrix. Due to the different diameters, the desired pre-stress is achieved when an appropriate pressure is applied on introducing the supporting matrix 13 into the envelope 4.

In the embodiment illustrated in Figure 5, the supporting matrices for the reduction catalyst and the oxidation catalyst are arranged or inserted in a common envelope 27. Distance between the catalysts is maintained by a spacing bar 28, which is constructed similarly to the bar or bars 21 in Figure 2. The secondary air connection 17 is fitted in the region of the spacing bar 28 and extends through an aperture in the wall of the envelope 27.

Figure 6 illustrates schematically a detail of the attachment between the cartridge 20, the housing 16 and the exhaust gas inlet pipe 14. The fixing of the envelope 4 of a cartridge 20 in the housing 16 is achieved by a Z-shaped flange 19. The bentover flange ends of which are secured by means of screws 18, on the one hand to the envelope 4 of the cartridge 20 and on the other hand to the housing 16. At the same time the construction is made such that the end of the exhaust gas inlet pipe 14 is clamped between one flange part of the ring flange 19 and the envelope 4. A particularly favourable guidance of the exhaust gas is achieved by this means. It may further be seen from Figure 6 that the space between the envelope 4 of the cartridge 20 and the housing 16 is packed with an insulation material 22. This insulation material may consist for example of asbestos, fibre glass or the like.

The manufacture of a supporting matrix according to Figures 1 or 2 can be performed advantageously with an apparatus of the kind shown schematically in Figure 7. Here the smooth or flat intermediate band 1 is fed from a supply reel (not shown), and from a further reel (not shown) comes second band which is shaped in a corrugating machine 5 into the corrugated band 2. The flat intermediate band 1 and the corrugated band 2 are then fed over guide rollers 7 to 10 and a return cylinder 11 to a coating bath 12 in which the catalyst material is applied to the two bands. After the coating operation, the bands 1, 2 are coiled in a winding machine 6 on to a core 3 up to the particular diameter desired. By means of shears or the like, not shown, the bands 1, 2 can then be cut after the desired diameter of the supporting matrix 13 has been reached, while the cut may be taken either at right-angles to the longitudinal axis, or as explained in conjunction with Figure 2, obliquely to the longitudinal axis of the bands. The bands 1 and 2 are then coiled again correspondingly onto a following core 3. The supporting matrix 13 is then next introduced under prestressing into an envelope 4. An appropriate tensile stress is applied to the bands during the coiling operation in order to achieve as dense a coil as possible.

The shape of the corrugations is schematically shown as sinusoidal for simplicity. However, in practice it is preferable for the profile of each corrugation to correspond to the profile of an involute gear tooth, the involute of any given curve being the path traced by a point on a taut, inextensible cord as it is unwound from a point on a convex curve. The height and spacing of the corrugations, for example, in the case of the supporting matrix shown in Figures 1 and 2, are chosen such that the cross-sectional width and height of the individual cells formed between bands 1 and 2 are smaller than 1.5 millimeters. The intermediate band 1 and corrugated band 2 preferably have a wall thickness which is less than 0.1 millimeters.

It is also possible, for example, instead of the bars 21, to use an appropriate wire grille or mesh. The bands 1 and 2 may be brazed or welded together in spots or continuously. The supporting matrices 13 may be secured in their respective envelopes 4 by screws, or by brazing or by welding.

WHAT I CLAIM IS:—

1. A catalytic reactor matrix for cleaning the exhaust gases of an internal combustion engine wherein said matrix comprises alternate flat and corrugated sheets of heat-resistant steel, as hereinbefore defined, said sheets being coated with a catalytically active material.

2. A matrix according to Claim 1, wherein the steel is catalytically inactive.

3. A matrix according to Claim 1 or Claim 2, wherein cross-sectional width and the height of the individual cells formed by the corrugations are less than 1.5 millimeters.

4. A matrix according to any one of the

preceding Claims, wherein the thickness of the sheets is less than 0.1 millimeter.

5. A matrix according to any one of Claims 1 to 4, wherein the profile of the corrugation of the corrugated sheet or sheets of the matrix corresponds to the profile of an involute gear tooth.

6. A matrix according to any one of Claims 1 to 5, wherein the sheets are generally flat and are stacked alternately one above the other.

7. A matrix according to any one of Claims 1 to 5, wherein the sheets consist of bands which are wound spirally together to form a cylinder.

8. A matrix according to Claim 6 or Claim 7, wherein the sheets are coated with a catalytically active metal before stacking or winding and are subsequently oxidised.

9. A matrix according to any one of Claims 1 to 7, wherein the sheets are coated with a catalytically active metal oxide.

10. A matrix according to any one of Claims 6 to 9, wherein the individual sheets are spot welded or brazed together.

11. A matrix according to any one of Claims 1 to 9, wherein the sheets are welded or brazed together along their whole areas of contact.

12. A matrix according to any one of Claims 1 to 9, wherein the smooth and the corrugated steel sheets are arranged under pre-stressing in a steel envelope.

13. A matrix according to Claim 12, wherein the envelope is of frusto-conical construction.

14. A matrix according to Claim 12, when dependent on Claim 7, wherein the outer ends of the steel sheets are cut obliquely to their longitudinal axes.

15. A matrix according to Claim 14, wherein the obliquely cut end extends helically once around the circumference of the interior of the envelope.

16. A matrix according to any one of Claims 12 to 15, wherein the sheets are attached metallically to the envelope.

17. A matrix according to Claim 16, wherein the sheets are attached to the envelope by screws.

18. A matrix according to Claim 16, wherein the sheets of the matrix are welded or brazed to the envelope.

19. A matrix according to any one of claims 12 to 18, wherein retaining means are arranged adjacent an end face of the matrix and determine the position of the sheets in the envelope.

20. A matrix according to Claim 19, wherein the retaining means are constituted by crossed struts.

21. A matrix according to Claim 19 or Claim 20, wherein the retaining means are resilient.

22. A matrix according to Claim 19, wherein the retaining means is a grille.

23. A catalytic reactor comprising a matrix according to any one of Claims 12 to 22 and a housing with connections for an exhaust gas inlet pipe and for an exhaust gas outlet pipe, wherein the matrix with its envelope is fixed in the housing and sealed thereto by flange rings.

24. A reactor according to Claim 23, wherein a secondary air supply connection to the matrix is provided in the housing.

25. A reactor according to Claim 23 or Claim 24, wherein the flange rings are of U-shaped section, one arm of the U-shape being attached to the housing and the other arm being attached to the envelope of the matrix.

26. A reactor according to Claim 23 or Claim 24, wherein the flange rings are of Z-shaped section and the exhaust gas inlet pipe and/or the exhaust gas outlet pipe is or are secured between the internal flange of the corresponding Z-shaped flange ring and the envelope of the matrix.

27. A reactor according to any one of Claims 23 to 26, wherein a first catalytic reactor matrix serving as a reduction catalyst and a second catalytic reactor matrix serving as an oxidation catalyst are arranged in the said housing, both matrices being according to any one of claims 12 to 22.

28. A reactor according to Claim 27 when dependent on Claim 24, wherein spacing means are arranged between the reduction catalyst and the oxidation catalyst, and the secondary air supply connection communicates with the matrices in the region of the spacing means.

29. A reactor according to any one of Claims 23 to 28, wherein at least the space between the axially outermost flange rings, the housing and the envelope is packed with an insulating material.

30. A method of manufacturing a matrix according to any one of Claims 1 to 7, comprising continuously feeding two strips of heat-resistant steel through a continuous coating bath in which said strips are coated with a catalytically active material, one of said strips having been passed previously through a corrugating means; arranging the coated strips in alternate laminations and securing the laminations together.

31. A method according to Claim 30, wherein the coated strips are laminated together and coiled by a winding means to form a matrix of predetermined diameter.

32. A method according to Claim 30 or 31, wherein said method includes pressing the matrix into an envelope by means of a multiple jaw chuck.

33. A catalytic reactor matrix for cleaning the exhaust gases of an internal combustion engine substantially as hereinbefore

described with reference to the accompanying drawings.

34. A method of manufacturing a catalytic reactor for cleaning internal combustion engine exhaust gases substantially as hereinbefore described with reference to the accompanying drawings.

JENSEN & SON,
Agents for the Applicants,
8, Fulwood Place,
High Holborn,
London, WC1V 6HG.
Chartered Patent Agents.

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1452982 COMPLETE SPECIFICATION

4 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

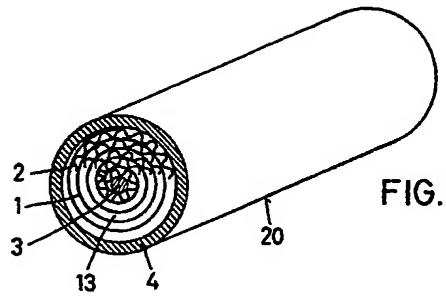

FIG. 1

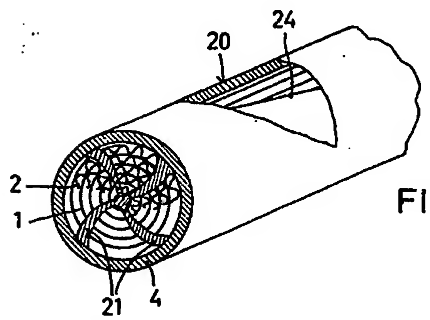

FIG. 2

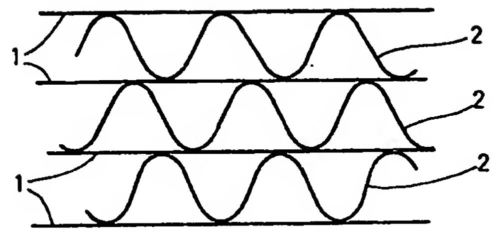

FIG. 3

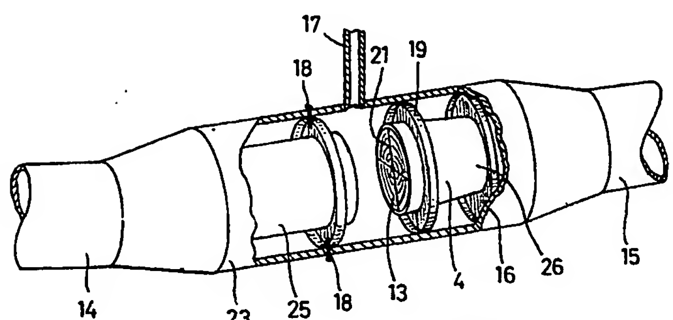

FIG. 4

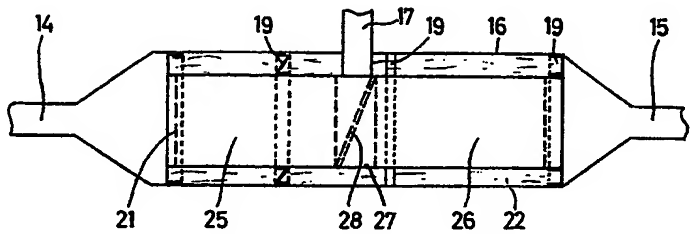

FIG. 5

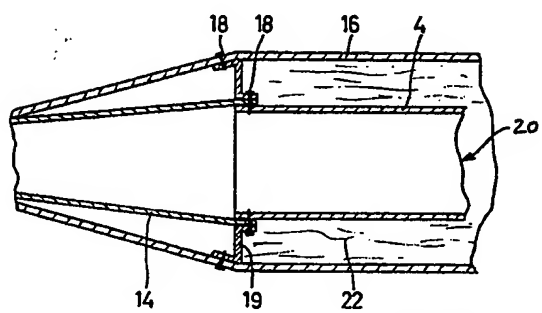

FIG. 6

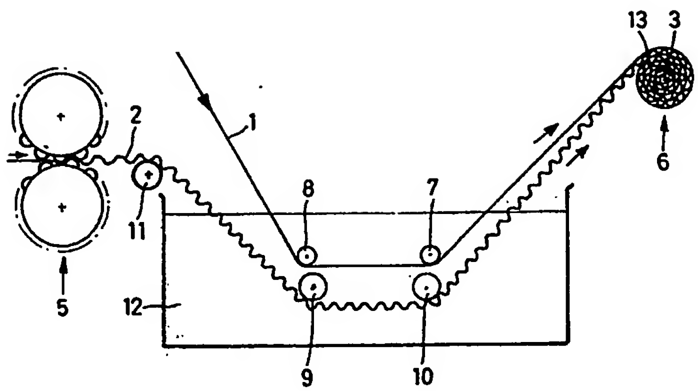

FIG. 7

DOCKET NO: E-80656

SERIAL NO:

APPLICANT: Rolf Brück

LERNER AND GREENBERG P.A.
P.O. BOX 2480
HOLLYWOOD, FLORIDA 33022
TEL. (954) 925-1100